

1 **DISK DRIVE COMPRISING AN ASYNCHRONOUS PARTITION LOCATED**
2 **ON A DISK BETWEEN TWO ISOCHRONOUS PARTITIONS**

3

4 **BACKGROUND OF THE INVENTION**

5 **Field of the Invention**

6 The present invention relates to disk drives. More particularly, the present invention
7 relates to a disk drive comprising an asynchronous partition located on a disk between two
8 isochronous partitions.

9 **Description of the Prior Art**

10 Disk drives may store both asynchronous and isochronous data. Asynchronous data is
11 transferred to and from the disk drive within a “best-effort” time interval, whereas isochronous
12 data is transferred to and from the disk drive within a “time-constrained” time interval. An
13 example of isochronous data is audio/video (AV) data transmitted from the disk drive to a
14 monitor for viewing. The AV data must be transmitted within a prescribed time interval in order
15 to avoid interruptions during the viewing session. An example of asynchronous data is user
16 application data, such as word processing documents, accounting documents, etc., manipulated by
17 an end user of a host computer. The transfer of asynchronous data to a host computer can be
18 interrupted (within some maximum time-out period) without significantly degrading the
19 performance of the host application.

20 Disk drives also typically employ error correction code (ECC) circuitry for correcting
21 errors on-the-fly in both the isochronous and asynchronous data. If the ECC circuitry is unable to
22 correct errors in asynchronous data, the disk drive typically performs various firmware retry
23 procedures in an attempt to correct the errors. The latency of the firmware retry procedures is
24 tolerated since it does not significantly degrade the performance of the host application while
25 ensuring the host application receives error-free data. If asynchronous data cannot be recovered
26 using the retry procedures, the disk drive responds with an error message rather than transfer bad
27 data to the host computer. In contrast, if the ECC circuitry is unable to correct errors in

1 isochronous data, the isochronous time constraints typically preclude using the firmware retry
2 procedures to correct the errors. This is not a significant problem since occasional errors in the
3 isochronous data do not significantly degrade the performance of the typical isochronous
4 application, such as streaming AV data to a monitor. Therefore the isochronous data, including
5 the errors, is typically transmitted by the disk drive to the host computer rather than respond with
6 an error message.

7 The disk within an isochronous/asynchronous disk drive is typically divided into an
8 isochronous partition for storing the isochronous data and an asynchronous partition for storing
9 the asynchronous data. An isochronous communication protocol, such as the AV/C protocol, is
10 used to access the isochronous partition according to the specified time constraints, and an
11 asynchronous communication protocol, such as the SBP-2 protocol, is used to access the
12 asynchronous partition in a best-effort manner. The asynchronous communication protocol may
13 also be used to access the isochronous data in a best-effort manner, for example, to edit a selected
14 portion of a video program.

15 It is desirable to support the concurrent (interleaved) transfer of both asynchronous and
16 isochronous data to and from the disk drive. If the isochronous and asynchronous partitions are
17 contiguous as illustrated in FIG. 1, the maximum seek distance may be from the inner diameter
18 track of the disk to the outer diameter track. If the disk drive is directed to make multiple
19 interleaved accesses to data located at the ends of the partitions, the cumulative seek times may
20 interfere with access to the time-constrained isochronous data. In addition, if the disk drive is
21 required to frequently seek between the asynchronous and isochronous data in order to satisfy
22 the isochronous time constraints, performance in accessing the asynchronous partition may
23 degrade.

24 There is, therefore, the need to ameliorate the inherent latency of seek times in a disk drive
25 which can interfere with the time-constrained access of isochronous data while concurrently
26 accessing asynchronous data.

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1 **SUMMARY OF THE INVENTION**

2 The present invention may be regarded as a disk drive comprising a disk having an
3 asynchronous partition and a first and second isochronous partition, wherein the asynchronous
4 partition is located between the first and second isochronous partitions in order to reduce the seek
5 time for the disk drive when seeking between the asynchronous and isochronous partitions. The
6 disk drive further comprises a head actuated radially over the disk, and a disk controller. The disk
7 controller is for writing data to and reading data from the first and second isochronous partitions
8 according to a time-constrained protocol, and is for writing data to and reading data from the
9 asynchronous partition according to a best-effort protocol.

10 In one embodiment, the time-constrained protocol employs the AV/C protocol, and the
11 best-effort protocol employs the SBP-2 protocol.

12 In one embodiment, the disk drive further comprises offset parameters for identifying the
13 beginning and end of the asynchronous partition. In one embodiment, the offset parameters
14 comprise a first parameter identifying the beginning of the asynchronous partition and a second
15 parameter identifying the end of the asynchronous partition. In another embodiment, the offset
16 parameters comprise a first parameter identifying the beginning of the asynchronous partition and
17 a second parameter identifying the size of the asynchronous partition.

18 In yet another embodiment, the disk comprises an AV file system for accessing the
19 isochronous data.

20 The present invention may also be regarded as a method of accessing a disk drive. The
21 disk drive comprises a disk and a head actuated radially over the disk. The disk comprises an
22 asynchronous partition and a first and second isochronous partition. The method comprises the
23 steps of using a time-constrained protocol to read isochronous data from at least one of the first
24 and second isochronous partitions, and using a best-effort protocol to read asynchronous data
25 from the asynchronous partition. The asynchronous partition is located on the disk between the
26 first and second isochronous partitions in order to reduce the seek time for the disk drive when
27 seeking between the asynchronous and isochronous partitions.

1 **BRIEF DESCRIPTION OF THE DRAWINGS**

2 FIG. 1 shows a prior art disk drive and the maximum seek distance between an
3 isochronous and asynchronous partition.

4 FIG. 2 shows a disk drive according to an embodiment of the present invention employing
5 a disk having an asynchronous partition located between two isochronous partitions which
6 reduces the maximum seek distance when seeking between the isochronous and asynchronous
7 partitions.

8 FIG. 3A illustrates the maximum seek distance when seeking between the isochronous and
9 asynchronous partition for the prior art disk drive of FIG. 1.

10 FIG. 3B illustrates the maximum seek distance when seeking between the isochronous and
11 asynchronous partitions for the disk drive of FIG. 2.

12 FIG. 4A illustrates the average random seek distance when seeking between the
13 isochronous and asynchronous partition for the prior art disk drive of FIG. 1.

14 FIG. 4B illustrates the average random seek distance when seeking between the
15 isochronous and asynchronous partitions for the disk drive of FIG. 2.

16 FIG. 5A illustrates the maximum seek distance when seeking between the ends of the
17 isochronous partition for the prior art disk drive of FIG. 1.

18 FIG. 5B illustrates the maximum seek distance when seeking between the ends of the
19 isochronous partitions for the disk drive of FIG. 2.

20 FIG. 6A illustrates the average random seek distance when seeking between two AV
21 streams stored in the isochronous partition for the prior art disk drive of FIG. 1.

22 FIG. 6B illustrates the average random seek distance when seeking between two AV
23 streams stored in different as well as the same isochronous partition for the disk drive of FIG. 2.

24 **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

25 FIG. 2 shows a disk drive 2 according to an embodiment of the present invention
26 comprising a disk 4 having an asynchronous partition 6 and a first and second isochronous
27 partition 8A and 8B, wherein the asynchronous partition 6 is located between the first and second

1 isochronous partitions 8A and 8B in order to reduce the seek time for the disk drive 2 when
2 seeking between the asynchronous 6 and isochronous partitions 8A and 8B. The disk drive 2
3 further comprises a head 10 actuated radially over the disk 4, and a disk controller 12. The disk
4 controller 12 is for writing data to and reading data from the first and second isochronous
5 partitions 8A and 8B according to a time-constrained protocol, and is for writing data to and
6 reading data from the asynchronous partition 6 according to a best-effort protocol.

7 In one embodiment, the disk drive 2 further comprises offset parameters 13 for identifying
8 the location of the asynchronous partition 6 with respect to the isochronous partitions 8A and 8B.

9 In one embodiment, the offset parameters 13 comprise a first parameter identifying the beginning
10 of the asynchronous partition 6 and a second parameter identifying the end of the asynchronous
11 partition 6. In another embodiment, the offset parameters 13 comprise a first parameter
12 identifying the beginning of the asynchronous partition 6 and a second parameter identifying the
13 size of the asynchronous partition 6.

14 Any suitable time-constrained and best-effort protocol may be employed. In one
15 embodiment, the time-constrained protocol employs the AV/C protocol, and the best-effort
16 protocol employs the SBP-2 protocol. The AV/C protocol is used to communicate with
17 audio/video equipment over an IEEE 1394 serial bus. The AV/C protocol uses the Function
18 Control Protocol (FCP) defined by IEC-61883, the ratified international standard for the transport
19 of audio/video command requests and responses. AV/C commands are transmitted through
20 AV/C transactions consisting of an AV/C command frame addressed to the target node's
21 FCP_Command register and zero or more AV/C response frames addressed to the requesting
22 node's FCP_Response register.

23 The AV/C Disk Subunit Enhancements for Hard Disk Drive Specification is a technical
24 specification of the 1394 Trade Association which includes enhancements to the AV/C protocol
25 for managing the storage and retrieval of audio/video (AV) data. Under this specification, AV
26 data is stored in the isochronous partitions 8A and 8B of the disk 4 in an AV track. An AV track
27 comprises a plurality of data sectors in one or both of the isochronous partitions 8A and 8B for

1 storing a stream of audio/video data. Each AV track is identified by a unique track ID in an entry
2 of an embedded AV file system stored on the disk 4. The entries in the AV file system are treated
3 as asynchronous data and accessed using a best-effort protocol to ensure the entries are
4 transmitted error-free to the host computer. In one embodiment, the entries of the AV file system
5 are duplicated to provide error correction redundancy.

6 The SBP-2 protocol for accessing the asynchronous partition employs Operation Request
7 Blocks (ORBs) which identify areas of the asynchronous partition 6 to read or write in terms of
8 Logical Block Addresses (LBAs). The disk controller 12 converts the LBAs into Physical Block
9 Addresses (PBAs) which identify physical sectors within the asynchronous partition 6. The LBA
10 to PBA addressing allows the disk drive 2 to “map-out” defective physical sectors using any
11 suitable defect mapping scheme.

12 FIG. 3A illustrates the maximum seek distance 14 when seeking between the isochronous
13 and asynchronous partition for the prior art disk drive of FIG. 1. In this example, the disk drive is
14 accessing an AV stream 16 at the extreme end of the isochronous partition, while concurrently
15 accessing (in an interleaved manner) asynchronous data 18 stored at the extreme end of the
16 asynchronous partition. Thus, the maximum seek distance 14 when seeking between the
17 isochronous and asynchronous data requires the entire stroke of the actuator arm. The associated
18 seek time may interfere with the time constraints of the isochronous data, particularly if the disk
19 drive performs multiple consecutive seeks to the end of the asynchronous partition. In addition,
20 the maximum seek distance 14 may degrade the performance in accessing the asynchronous data
21 18 if the disk drive is required to seek back and forth between the AV stream 16 in order to
22 satisfy the isochronous time constraints.

23 FIG. 3B illustrates how in the embodiment of FIG. 2 locating the asynchronous partition 6
24 between two isochronous partitions 8A and 8B significantly reduces the maximum seek distance
25 20A and 20B when seeking between the isochronous and asynchronous partitions. In one
26 embodiment, the isochronous partitions 8A and 8B are equal in size such that the maximum seek
27 distances 20A and 20B are equal in length. Also in the embodiment of FIG. 3B, the asynchronous

1 partition 6 is much smaller than the isochronous partitions 8A and 8B. Therefore the maximum
2 seek distances 20A and 20B are reduced in comparison to FIG. 3A to essentially one half the
3 stroke of the actuator arm (plus one-half the length of the asynchronous partition 6). This
4 reduction in seek distance and associated seek time improves performance by facilitating the time
5 constraints of the isochronous partitions 8A and 8B. It also improves performance with respect
6 to the asynchronous partition 6 by allowing more asynchronous data to be transferred to the host
7 computer before having to seek back to the isochronous partition to satisfy the isochronous time
8 constraints.

9 FIG. 4A illustrates the average random seek distance 22 when seeking between the
10 isochronous and asynchronous partition for the prior art disk drive of FIG. 1. On average, the
11 disk drive of FIG. 1 will access isochronous data 24 near the middle of the isochronous partition,
12 and access asynchronous data 26 near the middle of the asynchronous partition. Thus, the
13 average random seek distance 22 when seeking between isochronous and asynchronous data
14 requires one-half a stroke of the actuator arm.

15 FIG. 4B illustrates how in the embodiment of FIG. 2 locating the asynchronous partition 6
16 between two isochronous partitions 8A and 8B significantly reduces the average random seek
17 distance 28A and 28B when seeking between the isochronous and asynchronous partitions. In an
18 embodiment wherein the isochronous partitions 8A and 8B are equal and the asynchronous
19 partition 6 is significantly smaller than the isochronous partitions 8A and 8B, the average random
20 seek distance 28A and 28B is essentially reduced to only one-quarter a stroke of the actuator arm
21 (plus one-quarter the length of the asynchronous partition 6). This significant reduction in the
22 average random seek distance improves performance in satisfying the isochronous time
23 constraints and improves access to the asynchronous partition 6 by allowing more asynchronous
24 data to be transferred to the host computer before having to seek back to the isochronous
25 partition to satisfy the isochronous time constraints.

26 FIG. 5A illustrates the maximum seek distance 30 when seeking between the ends of the
27 isochronous partition for the prior art disk drive of FIG. 1. The maximum seek distance 30 when

1 concurrently accessing two AV streams 32A and 32B (in an interleaved manner) extends from
2 one end of the isochronous partition to the other end. FIG. 5B illustrates that the maximum seek
3 distance 34 for the disk drive of FIG. 2 when concurrently accessing two AV streams 36A and
4 36B. The maximum seek distance 34 extends through the asynchronous partition 6 from one end
5 of the first isochronous partition 8A to the other end of the second isochronous partition 8B
6 requiring the entire stroke of the actuator arm. In one embodiment, the size of the asynchronous
7 partition 6 is substantially smaller than the isochronous partitions 8A and 8B such that the
8 maximum seek distance is not significantly greater than the prior art of FIG. 5A. In an
9 embodiment wherein the size of the asynchronous partition 6 is significant, the AV streams are
10 stored in the isochronous partitions 8A and 8B to minimize the probability of concurrently
11 accessing two streams in separate partitions. For example, related AV streams likely to be
12 accessed together are stored in the same isochronous partition 8A or 8B so that the maximum
13 seek distance 38A or 38B does not extend through the asynchronous partition 6.

14 FIG. 6A illustrates the average random seek distance when seeking between two AV
15 streams stored in the isochronous partition for the prior art disk drive of FIG. 1. In the example
16 of FIG. 6A, the disk drive is seeking between an AV stream 40 located in the middle of the
17 isochronous partition, and an AV stream 42A or 42B located at an end of the isochronous
18 partition. The average random seek distance 44A or 44B equals one-half the length of the
19 isochronous partition. In an embodiment wherein the asynchronous partition is significantly
20 smaller than the isochronous partition, the average random seek distance 44A or 44B is essentially
21 one-half a stroke of the actuator arm.

22 FIG. 6B illustrates the average random seek distance when seeking between two AV
23 streams stored in separate as well as the same isochronous partition for the disk drive of FIG. 2.
24 When the AV streams 46A and 46B are stored in separate partitions, the average random seek
25 distance 48 equals one half a stroke of the actuator arm plus one-half the length of the
26 asynchronous partition 6. Thus, in an embodiment wherein the asynchronous partition 6 is
27 significantly smaller than the isochronous partitions 8A and 8B, the average random seek distance

1 48 is essentially the same as in FIG. 6A. When the AV streams are in the same partition (e.g., AV
2 streams 46A and 50), the average random seek distance 52 is reduced to one-half the length of the
3 isochronous partition 8A. In an embodiment wherein the isochronous partitions 8A and 8B are
4 equal and the size of the asynchronous partition 6 is significantly smaller than the isochronous
5 partitions 8A and 8B, the average random seek distance 52 is half the distance of the average
6 random seek distance 44A or 44B in FIG. 6A. In an embodiment wherein the size of the
7 asynchronous partition 6 is significant, the AV streams are stored in the isochronous partitions 8A
8 and 8B to minimize the probability of concurrently accessing two streams in separate partitions.